SHIP PRODUCTION COMMITTEE
FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
EDUCATION AND TRAINING

August 1987
NSRP 0281

THE NATIONAL SHIPBUILDING RESEARCH PROGRAM

1987 Ship Production Symposium

Paper No. 20: Proven Benefits of Advanced Shipbuilding Technology -- Actual Case Studies of Recent Comparative Construction Programs

U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
NAVAL SURFACE WARFARE CENTER

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **AUG 1987**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **The National Shipbuilding Research Program 1987 Ship Production Symposium Paper No. 20: Proven Beneifts of Advanced Shipbuilding Technology -- Actual Case Studies of Recent Comparative Construction Programs**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Naval Surface Warfare Center CD Code 2230 - Design Integration Tools Building 192 Room 128 9500 MacArthur Blvd Bethesda, MD 20817-5700**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

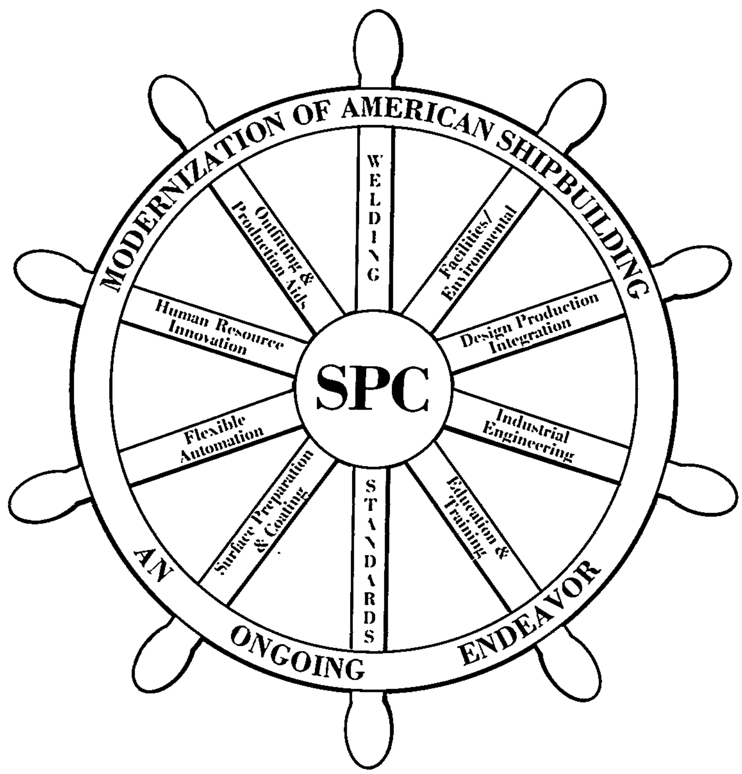
15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**16**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

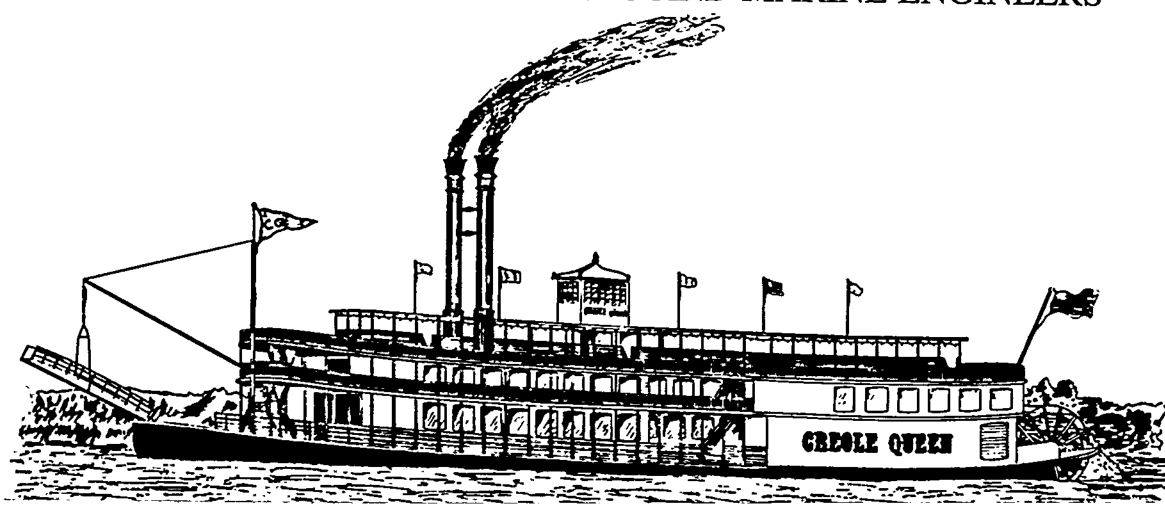
DISCLAIMER

N S R P
1987 SHIP PRODUCTION SYMPOSIUM



AUGUST 26-28, 1987
HYATT REGENCY HOTEL
New Orleans, Louisiana

HOSTED BY THE GULF SECTION OF THE
SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS



THE SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS
601 Pavonia Avenue, Jersey City, NJ 07306
Paper presented at the NSRP 1987 Ship Production Symposium, Hyatt Regency Hotel, New Orleans, Louisiana, August 26-28, 1987

Proven Benefits of Advanced Shipbuilding Technology—Actual Case Studies of Recent Comparative Construction Programs

No. 20

A. B. Nierenberg, Associate Member, and **S.G. Caronna**, Visitor, Avondale Industries, Inc., Avondale, LA

INTRODUCTION

Much has been written and discussed in the past decade concerning improved shipbuilding productivity meth-ods in U.S. Shipyards and a substantial amount of progress has been made in the implementation of methods, facilities and shipyard dedication to achieve a reduction in U.S. shipbuilding costs. Although productivity savings are often difficult to quantify, we will attempt to compare and contrast two (2) sets of comparable shipbuilding programs such that the definitive results of a comprehensive advanced shipbuilding methodology as employed at Avondale Shipyards since 1979 can be evaluated.

The programs to be evaluated are of excellent comparative nature, both in terms of ship characteristics as well as the contract environment under which they were executed.

The first set of comparable ships are both 40,000 DWT coastal tankers, one series built from a traditional approach for Ogden Marine with a contract authorization date in August 1978, and its counterpart program being a 1981 contract with Exxon Company which utilized the maximum implementation of the Avondale advanced shipbuilding methods from contract design throughout the construction program. Both programs were for shipyard developed designs and the ability to incorporate producibility oriented details was available in both programs. The principal characteristics of these vessels are contained in Table I [1-2].

The second set of comparable ships are Fleet Oiler programs for the U.S. Navy, in which the AO-177 Class Fleet Oilers were initially contracted for 1976 and processed through a traditional design and construction approach, as contrasted to the T-AO 187 Class Fleet Oilers which were contracted for in 1982 and developed with the full benefit of the advanced shipbuilding systems which had been under development and implementation at Avondale since 1979. The principal characteristics of these vessels are contained in Table II.

It is the intent of this paper to present a comparative study of the resultant ship construction process, methods and details, as compared to a dissertation on advanced shipbuilding methodology itself. For a discussion of the methodologies employed, the reader is referred to references [3-7].

Major Milestones

The first major quantification of the impact of advanced construction methods is obtained by reviewing the program major milestones including intervals between events and total contract completion (labor and material) at each stage of activity. Table III and IV indicate the intervals between major events for each of the vessels.

The significant improvement derived on both vessels built utilizing advanced shipbuilding techniques as compared to their predecessors is the high percentage of completion at the keel laying and launch milestones as well as the sizable time compression from keel to trials. These key factors are both highly influential in controlling shipbuilding costs as the maximum amount of work performed prior to keel is indicative of the more efficient shop fabrication and on-unit installation activities. Additionally the reduced keel to delivery time frame shortens the less efficient and manpower intense onboard activities. In general the advanced outfitted vessels had completed systems installed at time of launch, enabling post launch activities such as shaft alignment, operational testing, etc. to commence immediately upon launch. Figures 1, 2, 3, and 4 show each vessel during construction on the building ways where the degree of outfitting is evident. Figures 5, 6, 7 and 8 show each vessel at launch where the overall completion of each hull can be readily ascertained.

Table I Principal Characteristics - 40,000 DWT Coastal Tankers

	Ogden	Exxon
Length Overall	629'-3½"	635'-6"
Length, BP	610'-0"	610'-0"
Beam	105'-10"	105'-10"
Depth	60'-0"	60'-0"
Design Draft	38'-0"	38'-0"
Scantling Draft	43'-6"	42'-0"
Block Coefficient	.76	.80
Midship Coefficient	.997	.997
Length of Parallel Midbody	60'	180'
Horsepower, BHP	14,100	17,000
Cargo Capacity, Ft3	1,939,125	2,134,810
No. of Cargo Tanks	18	43
Ballast Capacity, Ft3	535,212	652,715
Fuel Oil Capacity, Ft3	108,064	53,900
Fresh Water Capacity, Ft3	11,800	12,400
Accommodations	36	27
Deadweight Tonnage @ Design Draft, LT	41,851	41,568
Lightship Weight, LT	11,186	14,473
No. of Cargo Pumps	18	43
Electrical Capacity, Kw	4 X 800	3 X 1600
Trial Speed, Kts	16.1	16.95
Type of Propulsion Machinery	Single Screw Medium Speed Geared Diesel	Single Screw Slow Speed Direct Coupled Diesel
Propeller	Fixed Pitch	Fixed Pitch

Table II Principal Characteristics - U.S. Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Length Overall	591'-6"	677'-6"
Length, BP	550'-0"	650'-0"
Beam	88'-0"	97'-6"
Depth	48'-0"	50'-0"
Design Draft	32'-0"	34'-6"
Scantling Draft	35'-0"	37'-10"
Block Coefficient	.61	.64
Midship Coefficient	.977	.981
Length of Parallel Midbody	None	None
Cargo Capacity, Barrels	120,000	180,000
Ballast Capacity, Ft3	305,695	415,077
Fuel Oil Capacity, Ft3	67,500	71,400
Fresh Water Capacity, Ft3	2,448	4,176
Total Deadweight @ Design Draft, LT	18,333	25,564
Lightship Weight, LT	9,053	14,711
Horsepower, BHP	26,700	33,000
Electrical Capacity, Kw	3 @ 2500	4 @ 2500
No. of Cargo Pumps	8	8
Accommodations	200	137
Trial Speed, kts	21.4	22.1
Type of Propulsion Machinery	Single Screw 600 psi Steam	Twin Screw Medium Speed Geared Diesel
Propeller	Fixed Pitch	CRP

Engineering

The two major impacts to the engineering effort as a result of the advanced shipbuilding methods are:

1) a highly structured drawing and material management approach such that individual unit by unit drawing presentation and staged material heirachy is provided to improve the planning capability and process flow through the shipyard, and

2) a condensed total period of performance such that all work which is capable of being performed in the shops or on units in defined in time to support this more efficient work stage.

Tables V and VI provide some engineering statistics for each program and vividly illustrates the increase in drawing count as a result of unit by unit or zone in lieu of complete system presentation of fabrication and installation details. Figure 9 graphically depicts the overall inpact to the engineering time period of performance. This requirement obviously increases the peak manning in engineering and when combined with the additional information required on engineering documentation explains the critical need to effectively plan the engineering and material procurement functions to support the ship construction effort.

Hull Structure

The hull structure for the types of vessel's under discussion is still the single largest cost group in the vessels construction and therefore careful attention to the method of construction, unit configuration, construction details and shipyard process flow are critical factors in minimizing shipyard costs. Furthermore, the basic concept of increasing the extent of on-unit outfitting of distributed systems must be accomplished without a negative impact to the basic cost of steel construction.

The primary producibility improvement in steel construction has been the process lanes concept, whereby all steel fabrication is grouped by common work process and performed in uniquely equipped work centers each designed to achieve the highest possible productivity. The key to obtaining the benefits from a process lanes approach is to properly plan each part of the steel fabrication process and to refine the design such that a maximum amount of repetitive type processes are possible.

Tables VII and VIII identify some of the key parameters of each vessels hull structure. Figure 10 depicts the mid-ship section unit breaks for each of the four (4) vessels. Extensive study and evaluation is performed prior to finalization of the basic hull unit break up on any vessel to assure that the best compromise of fabrication cost, unit erection cost and outfitting considerations are achieved. The relatively low average unit weights identified by tables VII and VIII are due to the inclusion of all units on the total count including masts, king-posts, bilge keels, rudders, etc., which tend to distort the absolute value. In general, main hull units at Avondale are limted to 120 tons from the fabrication platens and to 400 tons for combined unit erection lifts, such as superstructure sections.

Table III Major Milestones - Coastal Tankers

Interval	Ogden Months	Ogden % Complete	Exxon Months	Exxon % Complete
Contract to Start of Fab	13 months	-----	13 months	-----
Start of Fab to Keel Laying	6 months	20%	4 months	35%
Keel Laying to Launch	9 months	65%	8 months	85%
Launch to Builder's Trial	8 months	96%	4 months	98%
Builder's Trial to Delivery	1 month	100%	1 month	100%
Contract to Delivery	37 months	-----	30 months	-----
Keel to Delivery	18 months	-----	13 months	-----
Start of Fab to Delivery	24 months	-----	17 months	-----

Table IV Major Milestones - U.S.Navy Fleet Oilers

Interval	AO-177 Class Months	AO-177 Class % Complete	TAO-187 CLass Months	TAO-187 CLass % Complete
Contract to Start of Fab	18 months	-----	17 months	-----
Start of Fab to Keel Laying	3 months	15%	5 months	38%
Keel Laying to Launch	11½ months	60%	11 months	82%
Launch to Builder's Trial(BT)	15 months	97%	10½ months	98%
BT to Acceptance Trial (AT)	3½ months	99%	1½ months	99%
AT to Delivery	1 month	100%	1 month	100%
Contract to Delivery	52 months	-----	46 months	-----
Start of Fab to Delivery	3 months	-----	29 months	-----

Table V Engineering Deliverable Parameters - Coastal Tankers

	Ogden	Exxon
No. of Engineering Drawings	916	1612
Time Period-Contract to Engineering Essentially Complete	24 Months	18 months
Engineering Percentage Complete at Keel Laying	45%	70%
Relative Manhour Cost per Drawing	1.0	1.15
Peak Engineering Spending MHrs/Month	18,000	30,000

Table VI Engineering Deliverable Parameters - U.S. Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
No. of Engineering Drawings	1417	1844
Time Period-Contract to Engineering Essentially Complete	30 months	24 months
Engineering Percentage Complete At Keel Laying	40%	65%
Relative Manhour Cost per Drawing	1.0	.90
Peak Engineering Spending MHrs/month	23,000	44,000

Table VII Hull Steel Comparison - Coastal Tankers

	Ogden	Exxon
Hull Steel Weight, LT	9836	10,446
No. of Hull Units	128	144
Average Weight/Unit, LT	77	70
Percent Complete at Keel Laying	15	25
Percent Complete at Launch	98	100
Relative Hull Steel Cost	1.0	0.80

Table VIII Hull Steel Comparison - U.S.Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Hull Steel Weight, LT	6,482	10,756
No. of Hull Units	136	191
Average Weight/Unit, LT	47	56
Percent Complete at Keel Laying	10	20
Percent Complete at Launch	95	100
Relative Hull Steel Cost	1.0	0.72

Package Units

One of the most significant improvements in ship construction methods has been the development of large multi-system machinery/ piping package units. These shop fabrication assemblies encompass a sizable physical portion of a space or flat and include equipment, foundations, walkways, piping, instrumentation, etc. The package units are fully assembled, pressure tested and finally painted prior to mounting on individual hull units or loading onboard after the erection of adjacent hull units. Figures 11 and 12 illustrate typical machinery and deck package units.

Tables IX and X illustrate the extensive application of package units on the advanced construction vessels. In the case of the Exxon vessels, the package units represented a full 6% of the vessels lightship vessel and contained over 30% of the vessels piping footage.

Piping

Piping historically has been the second largest cost group in the ship production process In conventional construction methods piping installation usually dictated the total post launch schedule, as system and compartment completion and testing could not commence until piping installation was complete. The single most dramatic accomplishment of the advanced shipbuilding methodology was that piping installation and completion no longer became the pacing element of ship construction. This total change in ship construction priorities occurred as a result of package unit ap-

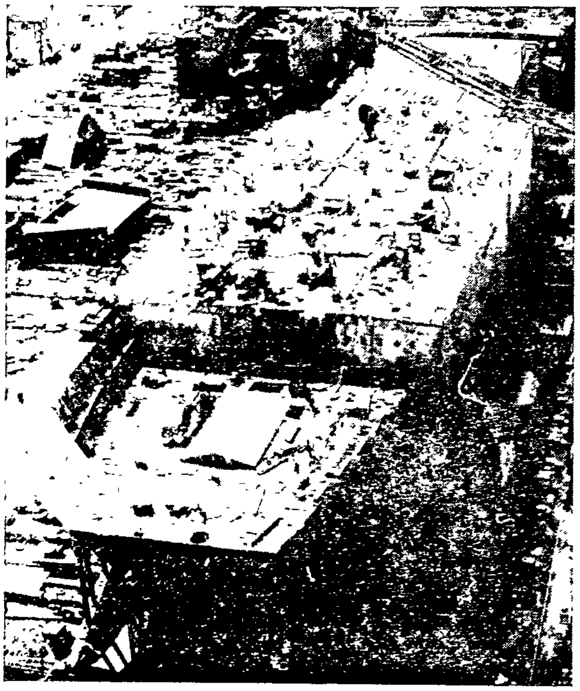


Figure 1
Ogden Dynachem Under Construction.

Figure 2
Exxon Charleston Under Construction

plication, extensive on-unit pipe installation and total material definition for the piping installation at the drawing level. The structure of tables XI XII vividly demonstrate the improvement in piping system installations with the later vessels having virtually all pipe installed at launch.

The changes in this cost group directly affect the costs of other supporting and interfacing crafts and the total contribution to improved shipbuilding costs are therefore even greater than actually indicated.

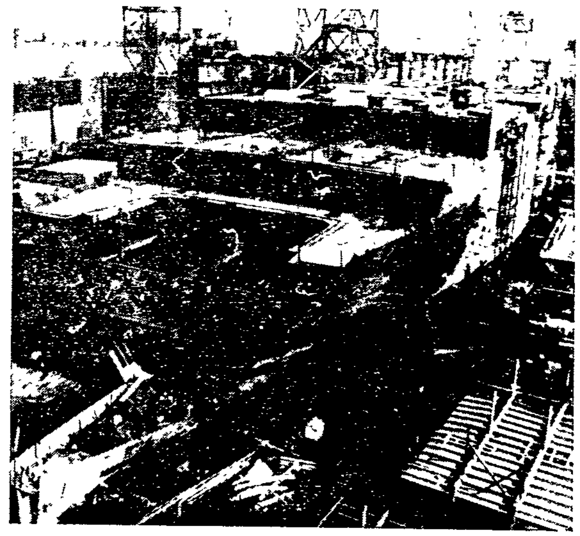


Figure 3
AO-177 Under Construction

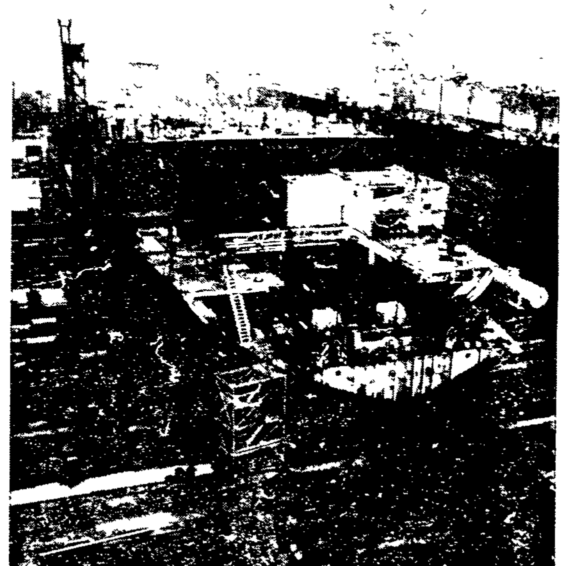


Figure 4
T-AO187 Under Construction

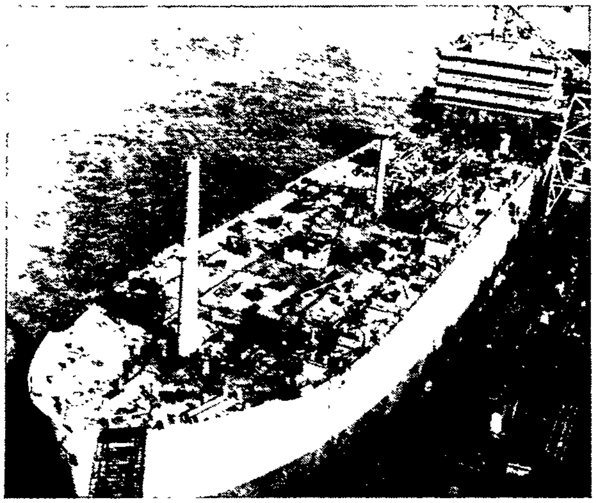


Figure 5 Ogden Dynachem at Launch

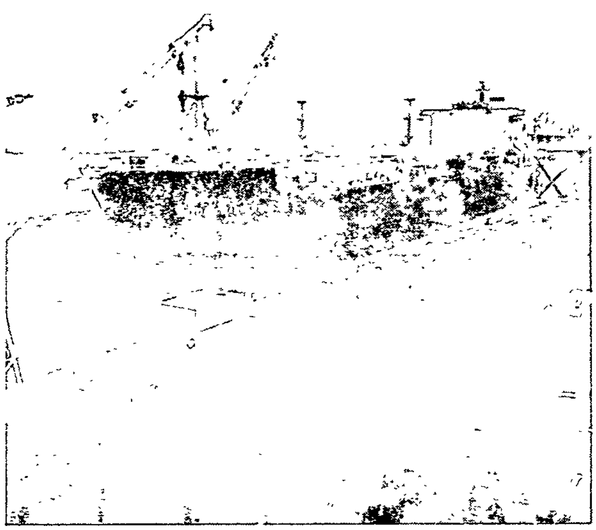


Figure 6
Exxon Charleston At Launch

Machinery

The machinery crafts have basically been an indirect beneficiary of the advanced shipbuilding methods, but the improvement in their costs have been substantial as well. Generally speaking, the advent of package units and on-unit outfitting has enabled the final installation of many pieces of equipment to take place in more accessible shop and platen environments with readily available handling gear in lieu of having to load equipment into the hold of the ship after unit erection.

Conscious efforts have been put forward to pre-machine foundations before installation and to adopt improved machinery and technology to further reduce machinery costs.

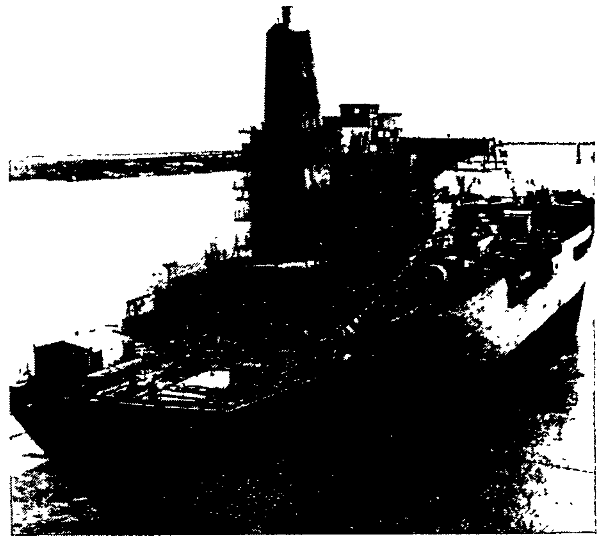


Figure 7 AO-177 At Launch

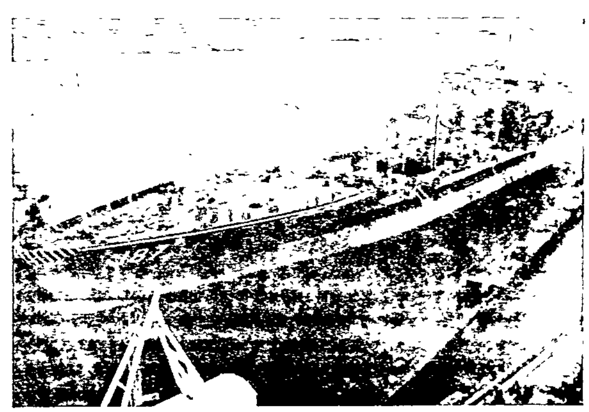


Figure 8 AO-187 At Launch

Table IX Package Unit Application - Coastal Tankers

	Ogden	Exxon
No. of Package Units	0	58
No. of Equipments Included	-	93
Footage of Pipe Included, Ft	-	45,000
Square Footage of Included Area, Ft^2	-	25,300
Weight of Package Units, LT	-	875

Table X Unit Application - U.S.Navy Fleet Oilers

AO-177 Class	T-AO 187 Class	
No. of Package Units	0	51
No. of Equipments Included	-	135
Footage of Pipe Included, Ft	-	25,000
Square Footage of Included Area, Ft^2	-	9,500
Weight of Package Units, LT	-	475

Table XI Piping Installation Comparison - Coastal Tankers

	Ogden	Exxon
Total Pipe Footage, LF	150,000	140,000
Percentage Shop Fabricated	60	65
Percentage Field Run	40	35
Number of Pipe Details	9,500	12,000
Average Length of PD, FT	9.5	7.6
Footage Installed on Package Units	0	45,000
Footage Installed On-Unit	10,000	55,000
Footage Installed Onboard	140,000	40,000
Pipe Installed At Launch, Percent	72	97
Relative Total Pipe Cost	1.0	0.85

Table XII Piping Installation Comparison - U.S. Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Total Pipe Footage	125,000	165,000
Percentage Shop Fabricated	60	68
Percentage Field Run	40	35
Number of Pipe Details	10,200	12,238
Average Length of PD	7.4	8.8
Footage Installed on Package Units	0	25,000
Footage Installed On-Unit	6,000	90,000
Footage Installed Onboard	119,000	50,000
Pipe Installed At Launch, Percent	60	98
Relative Total Pipe Cost	1.0	0.78

Special tools are designed as part of the engineering process as the "how to build" is now an integral part of the engineering design process.

Coatings

Coatings have grown to be an ever more complex part of the shipbuilding process and now represent the third largest cost constituent in ship construction costs. This is attributable to both the increased sophistication of coating systems intended to reduce long term maintenance as well as greater awareness of surface preparation requirements, system compatibilities, etc. Direct cost comparisons between different contracts are still difficult due to the varying specification requirements invoked by different customers. However, the most significant contribution by the coating process to the total shipbuilding cost structure has been the early individual subassembly and on-unit surface preparation and coating emphasis. This approach has reduced the extent of final surface preparation and coating to be done onboard and in conjunction with the earlier installation of other distributed systems a minimum of onboard blasting is therefore required. The coating process, although still re-

Table XIII Machinery Installation - Coastal Tankers

	Ogden	Exxon
No. of Package Unit Installations	0	93
No. of On-Unit Installations	0	160
No. of Onboard Installations	343	195
Percentage Complete at Time of Launch	55	80
Relative Cost	1.0	0.85

Table XIV Machinery Installation - U.S.Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
No. of Package Unit Installations	0	135
No. of On-Unit Installations	0	300
No. of Onboard Installations	708	225
Percentage Complete at Time of Launch	40	85
Relative Cost	1.0	0.80

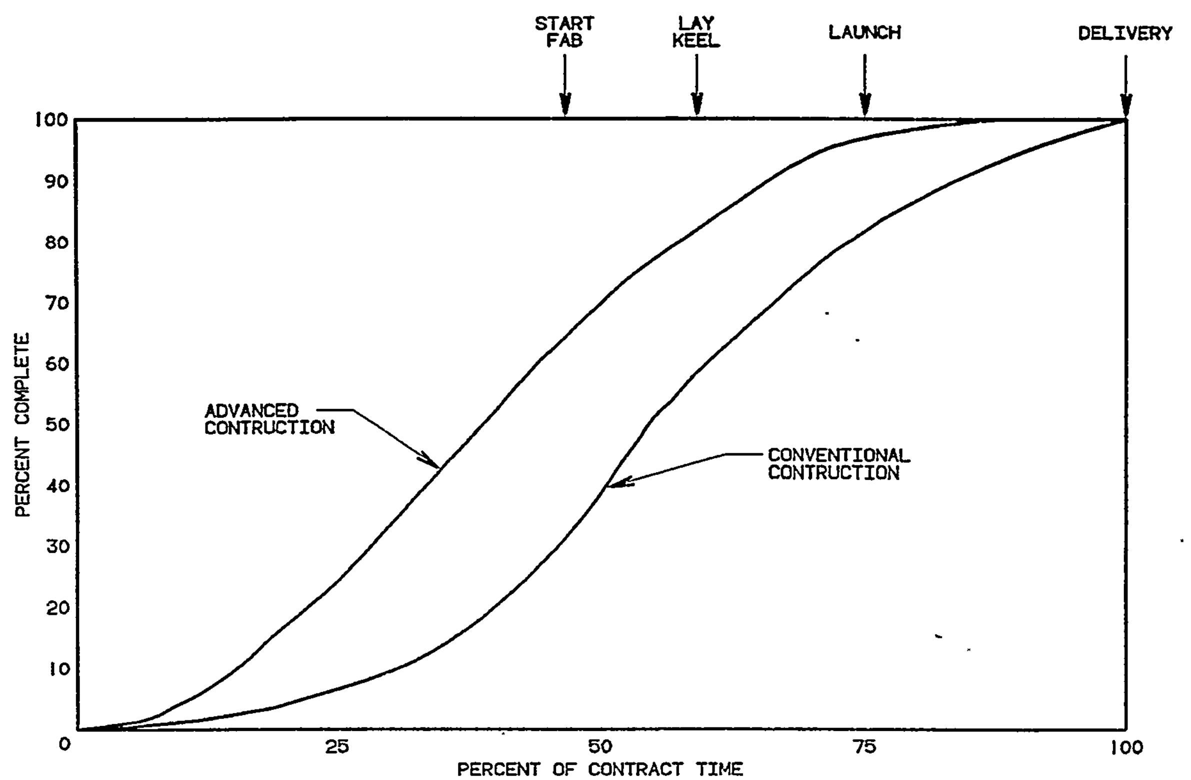


Figure 9 Engineering Progress

quiring its fair share of time prior to ship completion, is less of a governing factor in ship schedule and cost than in the past.

Sheetmetal

Sheetmetal work breakdown was often difficult to quantify to the outsider as product definition and ship detailing was generally handled directly by the crafts. The outgrowth of a disciplined advanced shipbuilding process has been to quantify the extent of shop fabricated ventilation details, identify the subassembly material re-

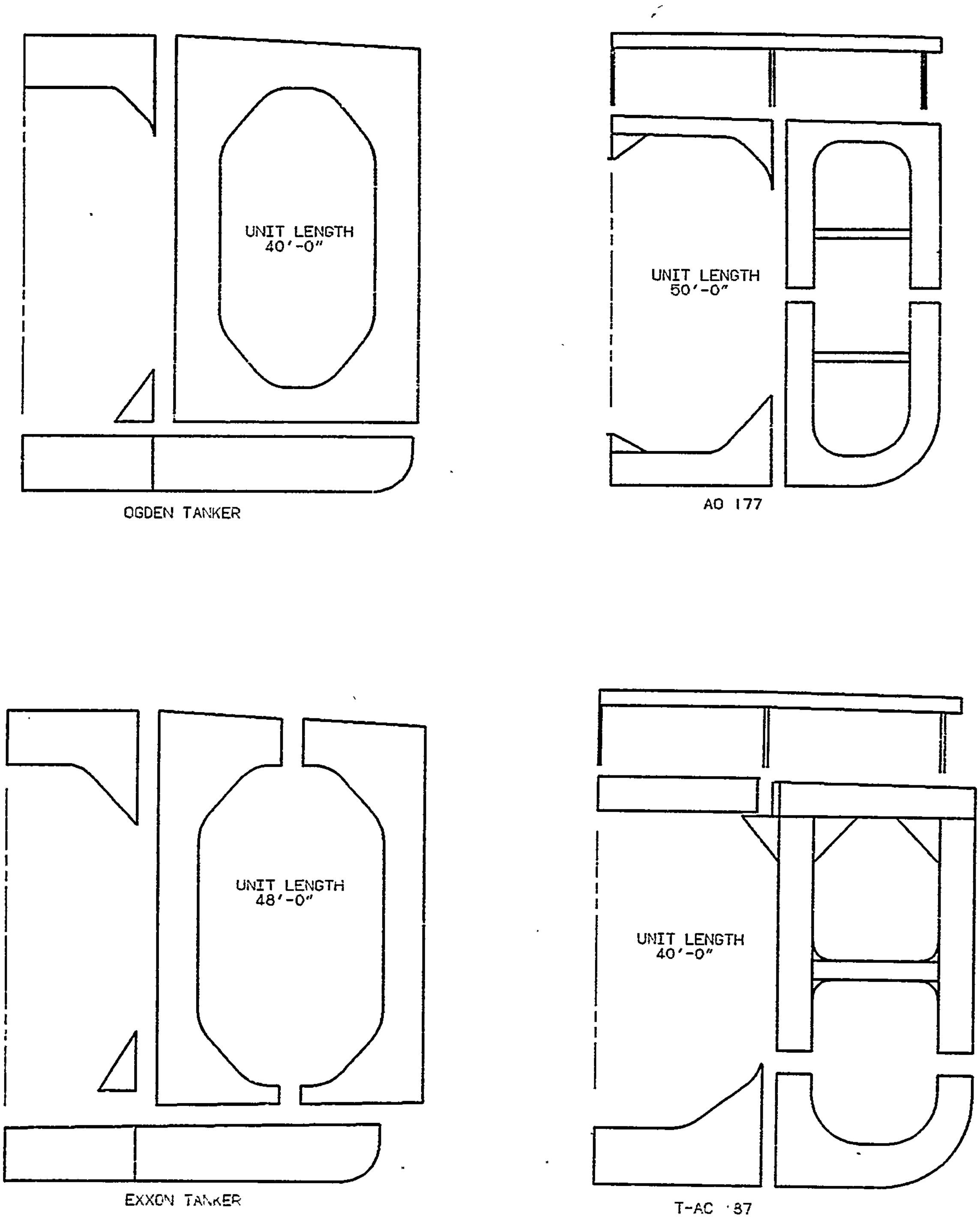


Figure 10 Midship Section Unit Breakup

Table XV Coatings Comparison - Coastal Tankers

	Ogden	Exxon
Square Footage Coated	1,850,000	2,135,000
Weight of Coating System, LT	130	210
% Complete at Launch	30	80
Relative Cost	1.0	.90

Table XVI Coatings Comparison - U. S. Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Square Footage Coated	1,400,000	2,360,000
Weight of Coating System, LT	100	160
% Complete at Launch	40	80
Relative Cost	1.0	.85

Table XVII Sheetmetal Installation - Coastal Tankers

	Ogden	Exxon
Percent on-Unit	10	55
Percent Onboard	90	45
% Installed at Launch	30	90
Relative Cost	1.0	0.85

Table XVIII Sheetmetal Installation - U.S.Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Percent On-Unit	10	80
Percent Onboard	90	20
% Installed at Launch	30	95
Relative Cost	1.0	0.82

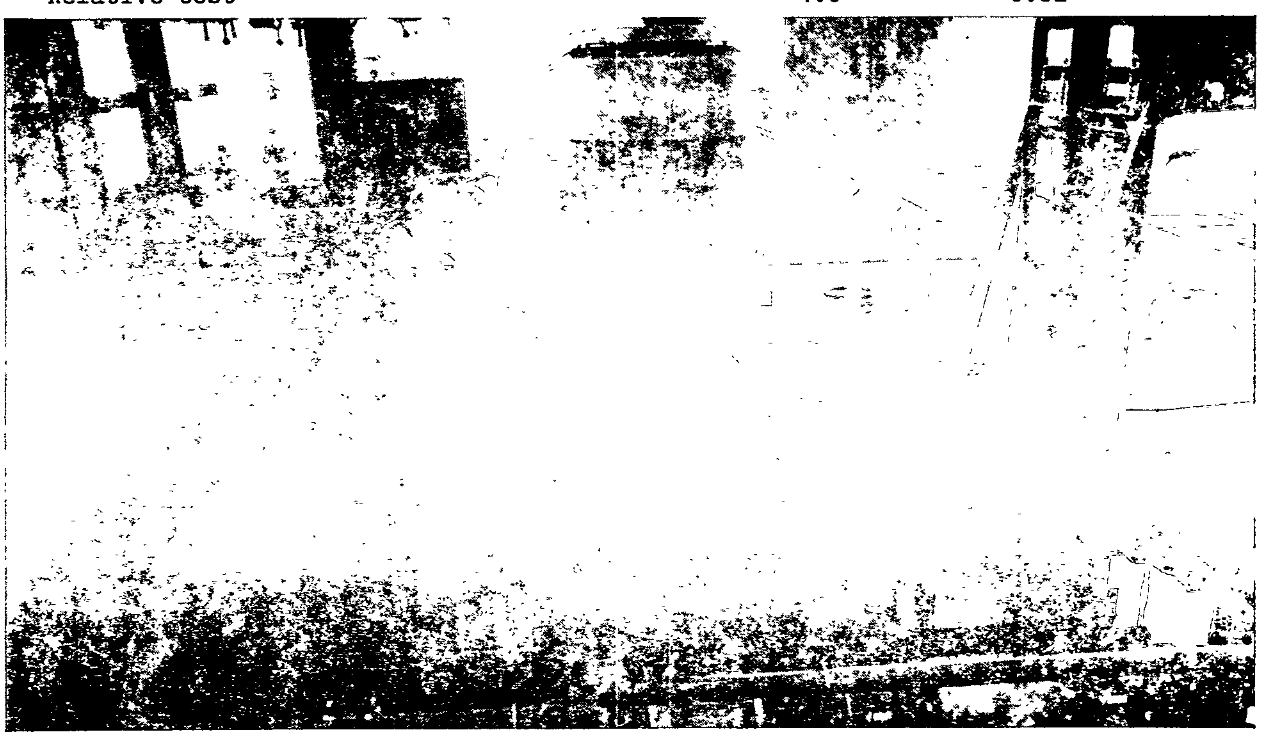


Figure 11 Typical Machinery Space Package Unit

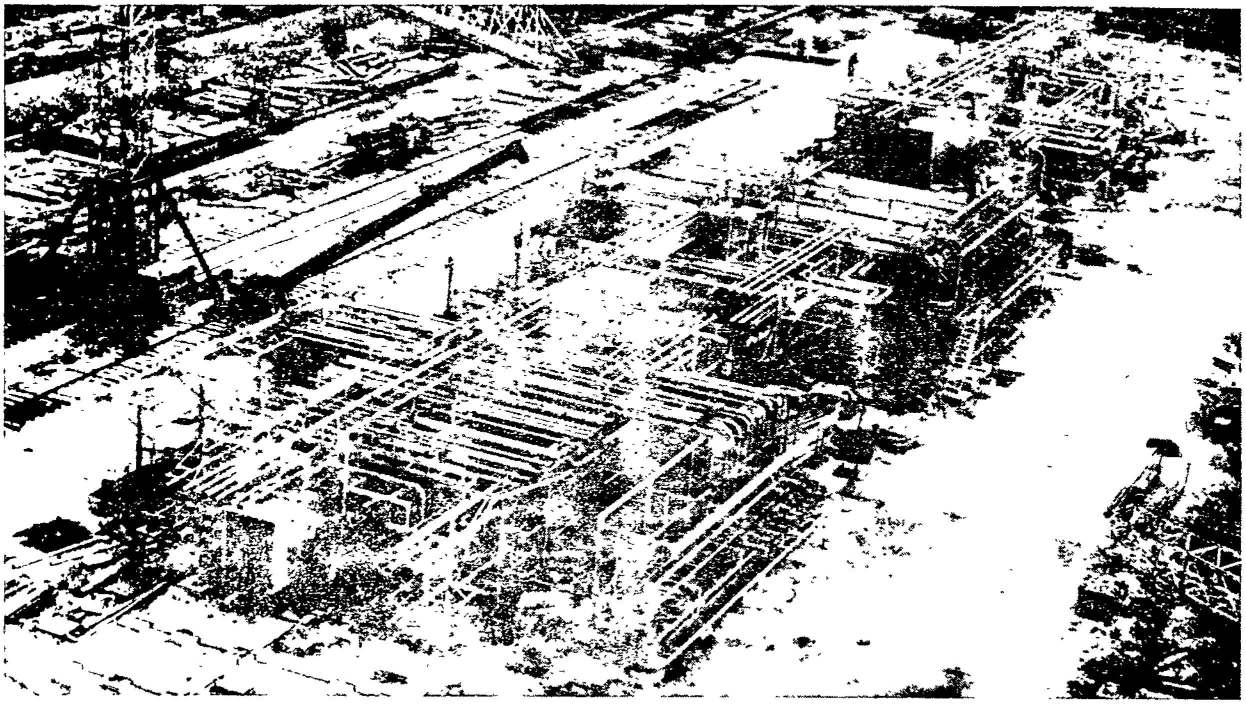


Figure 12 Main Deck Package Unit Assembly

quirements, and enable detailed planning and schedule monitoring to be performed.

The on-unit installation of sheetmetal has taken several forms, one being an increased reliance on built in trunks where the arrangement and weight considerations allow, and secondly the on-unit installation of extensive portions of the ventilation systems. Where large sections of sheetmetal exist, a highly integrated approach to assure proper coating and hull insulation prior to sheetmetal installation has been required.

Electrical

Advances in electrical productivity may at first seem less pronounced if one only focuses on cable installation and hookup which obviously requires a fairly substantial portion of the vessel to exist in order to be cost effective. However, when one looks at the extensive amount of effort required independent of cable installation, substantial productivity improvements can be made in wireway installations, local layout, equipment layout and installation, etc. Additionally, the earlier completion of all other craft work enables the earlier start of cable installation onboard with dramatic improvements in cable installation completion at launch. All vessels launched at Avondale since 1979 have had sufficient electrical installation complete and tested such that the ship's shore power electrical distribution system was able to be energized at time of launch.

Facilities

The continued investment in shipyard facilities obviously plays a large role in improving construction capability and enhancing productivity. Avondale has made substantial investments in facilities over the past 15 years, including the past eight (8) years during which the four (4) classes of vessel under discussion were constructed. Highlights of the major facilities improvements in this time period are as follows:

1979 - Activation of Semi-Automated Pipe Shop
1980 - Application of Line Heating
1982 - Installation of Pin Jigs
1982 - Establishment of Process Lanes Construction Platens
1983 - Installation of 265 Ton Gantry Crane
1985 - Installation of 400 Ton Turn-Over Crane

Each of the classes of vessels were basically constructed in the same physical areas of the shipyard and the restraints of physical unit weight and dimensions were basically unchanged during this time period. The increased lifting capacity gantry crane was installed to enable installation of the

Table XIX Electrical Installation - Coastal Tankers

	Ogden	Exxon
Cable Footage	325,000	490,000
Cable Percent Installed at Launch	65	85
On-Unit Installations, %	5	20
Relative Cost	1.0	.90

Table XX Electrical Installation - U.S.Navy Fleet Oilers

	AO-177 Class	T-AO 187 Class
Cable Footage	612,000	905,000
Cable Percent Installed at Launch	65	80
On-Unit Installations, %	5	40
Relative Cost	1.0	.85

completely asembled T-AO main engine in lieu of reassembly of the engine in the ship as done on the Ogden and Exxon vessels. This increased lifting capacity in the hull erection area does not affect unit size due to other process lane and painthouse size and weight restraints. The larger total lift capacity now available in the assembly area does enable the "blocking" of several units prior to erection. This capability is principally utilized for large volume, lower weight type superstructure units.

Conclusion

We have attempted to depict through the tables and figures that the benefits of advanced shipbuilding methods at Avondale have been considerable in the period of implementation from 1979 to the present. It is often difficult to clearly quantify the improvements that have been made, as we clearly live in an ever changing environment of increased contract requirements, changing social and economic factors,and the absence of a series of standard ship designs. However, the results in every measure of shibuilding productivity support the implementation of improved methodology as done at Avondale and other domestic shipyards.

I believe the U. S. Shipbuilding Industry has made significant progress in improved productivity gains in the recent past and we see these techniques being just as effectively implemented on complex U. S. Navy construction programs as well. I'm sure we all look forward to the return of a domestic commercial shipbuilding market such that our newly acquired skills can be applied to a greanter volume of ship production.

Acknowledgements

We would like to express our sincere appreciation to all the individuals of IHI who worked with Avondale over the past several years in developing the improved methods now in place. Additionally, we would like to acknowledge all of the employee owners at Avondale that work hard every day to achieve the benefits of what is very advantageous, but also a very vigorous methodology of ship construction.

References

1. McAlear, R.J. and Nierenberg, Alan B. "Design of a 42,00 DWT Chemical/Product Carrier", Transactions. SNAME Vol. 87, 1979

2. Koops, Dwight H., Caldwell, Robert X, and Gordon, Maurice, "Two State-of-the-Art Specialty Product Ships," Transactions SNAME Vol. 92 1984

3. Avondale Shipyards, Inc., "Manufacturing Technology for Shipbuilding; Planning and Sched-uling, Volume I," NSRP Report 0137, July 1982

4. Avondale Shipyards, Inc., "Manufacturing Technology for Shipbuilding; Design Engineering for Zone Outfitting, Volume II," NSRP Report 0138, July 1982.

5. Avondale Shipyards, Inc., "Manufacturing Technology for Shipbuilding; Moldloft, Production Control, Accuracy Control, Volume III," NSRP Report 0139, November 1982.

6. Avondale Shipyards, Inc., "Manufacuring Technology for Shipbuilding; Process Lanes and Design Engineering for Zone Outfitting, Volume IV," NSRP Report 0140, 1984.

7. SNANE Ship Production Committee Education and Training Panel (SP-9) "Manufacturing Technology for Shipbuilding - Project Condensation" University of Michigan Contract No. DTMA-91-82-C20022, Feb. 1986.

Additional copies of this report can be obtained from the National Shipbuilding Research and Documentation Center:

http://www.nsnet.com/docctr/

Documentation Center
The University of Michigan
Transportation Research Institute
Marine Systems Division
2901 Baxter Road
Ann Arbor, MI 48109-2150

Phone: 734-763-2465
Fax: 734-763-4862
E-mail: Doc.Center@umich.edu